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ABSTRACT

Presented is a description of a physics program format used, with a high degree of success, at Boyertown Area Senior High School in Pennsylvania. The program features integration of desirable curriculum innovations such as individualization with a recognized curriculum (Project Physics) while maintaining the quality of a solid first year physics course. The program utilizes trained student assistants, behavioral objectives, progress level testing, and mastery learning to achieve an optimum degree of individualized physics instruction. (Authors/PEB)

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INDIVIDUALIZATION OF PHYSICS FOR INCREASED ENROLLMENT THROUGH MODERN INSTRUCTIONAL TECHNIQUES

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RATIONALE

The nationwide decline in high school physics enrollments is a well-documented fact (5) and the percentage drop may be misleading in the light of recently rising high school enrollments. As total high school enrollments decline in the mid and late '70s, the severity of the physics decline will probably become more widely appreciated.

National curriculum efforts have in part, attempted to directly or indirectly develop sufficiently attractive programs to halt or reverse the decline. Regional and local efforts have also joined the chorus. The Boyertown project is a localized attempt to model a physics program after a successful secondary science methods course; the overall objective was to boost static physics enrollments.

The Boyertown Area Senior High School of Boyertown, Pennsylvania, has experienced a high degree of success in administering a new physics program format. Primary goals of the change were to increase enrollment, achievement, and interest by shifting the instructional strategies toward increasing degrees of individualization. The program features integration of desirable curriculum innovations with a recognized curriculum (Project Physics) and simultaneously maintains the quality of a solid first year physics course. Responding to research findings and current trends in the teaching of secondary science, the Boyertown Project utilizes trained student assistants, behavioral objectives, progress level testing, and mastery learning to achieve an optimum degree of individualized physics instruction.

PROGRAM DESCRIPTION

Individualization

Initially the students are given standardized tests (6) and teacher-made questionnaires designed to determine each student's specific abilities, skills, interests, and goals. These results, when interpreted and subsequently coordinated

with guidance counseling information and records of past performance, provide the teacher with a tentative "jumping off point" for beginning the year's work with each student.

The program is designed to meet the general needs of all the students and simultaneously selected specific needs of each physics student. All students undertake a basic core of instruction which consists of three to five lectures and/or discussion sessions per week. Also, all students are asked to carry out one assigned laboratory period per week. As in a more traditional framework, the program also includes occasional guest speakers, field trips, films, and other appropriate educational experiences throughout the year.

Beyond this, every student is encouraged and guided to select optional experiences which will correspond with his or her interests and goal choices as previously stated on the initial questionnaire. The instructor must, in this regard, act to insure that the choices regularly made by students are realistic, meaningful, and sufficient to provide adequate preparation for the student's stated goals. Optional activities generally consist of problem solving sessions and discussions, individualized project development, remedial tutoring with trained student aides, peer teaching in remedial topics, library research on appropriate and approved topics, detailed investigation of core concepts, or investigation of advanced topics.

Student Aids

The many choices available to students during optional activity periods dictate that the classroom displays a variety of teaching-learning situations simultaneously. To carefully manage activities and still maintain classroom control and exert quality control for all students, the teacher uses trained student assistants acting as aids. The aids are seniors who are selected from those students having successfully completed physics during their eleventh grade.

These students are selected on a basis of serious interest and subject competency and are given a prestigious peer status in the performance of their duties. Typical duties include: 1) small group instruction in measuring procedures, equipment operating procedures, and laboratory safety procedures; 2) a variety of clerical record duties; 3) remedial instruction in algebraic operations on equations, slide rule proficiency, unit conversions between measurement systems; and 4) the dispensing and collecting of equipment and supplies. Although these student assistants are veteran physics students, a meeting is held weekly to discuss the following week's activities, text material, special working conditions, etc. This enables them to prepare to efficiently perform their duties and impresses upon them the need to do so. It has been found that instruction may be optimized by varying the number of assistants used during the optional activity periods between one and N depending upon the class size and the number (N) of separate sub-groups that are likely to form. The magnitude of the contribution of these assistants is immense and they seem critically necessary to provide a program which allows constructive individualized activities to proceed.

Instructional Objectives

Instructional objectives have been developed for the course to aid in determining the instructional mode (8) and to precisely spell out the expected behavior changes for the students. At this point, it may be useful to recall that an instructional objective is a precise statement of student behavior or observable product of student behavior; it may be used to provide evidence to support an inference that learning has or has not occurred. Such a statement usually defines the specific behavior expected, the conditions under which the behavior is to occur, and the minimum level of acceptable performance on that objective (4).

The following is an example of an instructional objective from the Boyertown

Project. Each academic physics student, given a problem in vector composition similar to the following:

> Two forces are acting simultaneously on a given object. One of the forces is 10.0 nt. and is directed on a bearing of 090° and the second force is 15.0 nt. and is directed on a bearing of 180°. Determine the magnitude and direction of the resultant force,

will demonstrate in writing the following techniques and skills in developing a solution: a) sketch and correctly label the problem, b) make a determination of the magnitude of the resultant using the Pythagorean Theorem or trigonometric functions, c) make a determination of the bearing of the resultant using trigonometric functions, d) obtain the correct resultant magnitude, e) obtain the correct resultant bearing. Successful achievement of this objective requires a minimum of four of the five specified points listed above. Partial credit rating corresponds to the percentage of the five specified points successfully completed.

The objectives used in the Boyertown Project were developed by the author and represent a sampling of physical theory from the areas of measurement, motion, mechanics, astronomy, electromagnetics, and nuclear concepts. Furthermore, the objectives range in cognitive level from knowledge (memorization) through synthesis (1). A controlled sampling of the course's core instructional objectives provides the basis for unit testing of each student in order to assess the level of his or her achievement of the desired objectives within any given unit.

In addition to the cognitive levels described above, the students are encouraged to engage in synthesis and evaluation (1) of ideas by applying their energies in the form of individual research projects. An ex-storage room has been converted into a student research laboratory so that the students may apply and test their ideas using setups which are isolated from routine class traffic.

Instructional objectives have also been developed to describe desirable behavioral changes in the affective domain (i.e. feelings or attitudes). These objectives focus on the frequency of approach behaviors exhibited by a student and are recorded within an anecdotal record.

Mastery Learning

Mastery learning is also an important aspect of the Boyertown Project. Mastery learning implies the successful completion of one task or objectives of an instructional sequence before undertaking of subsequent tasks or objectives (2). An example of the mastery relationship might be the following: A student who attempts to construct a graph from tabularized experimental data for the purpose of interpolation or extrapolation of data can generally do so only after he has mastered a minimum set of the techniques of graphing; e.g., he must possess the knowledge and comprehension of coordinate axes, scales, coordinate points, methods of connecting points, and be able to apply these concepts before he can construct an accurate graph and interpret it successfully.

The mastery aspect of the Boyertown Project requires that the student demonstrate mastery of such topics as graphing operations, unit conversions, slide rule techniques, and calculator operations before engaging in higher level learning tasks. Most teachers will concur with the frustration and apparent futility encountered while attempting to transfer concepts and processes to students who have failed to master the necessary cognitive and psychomotor prerequisites. Mastery of the lower level objectives helps the teacher determine when each student is "ready" to investigate higher level ideas. This readiness increases the probability of student success which in turn may induce motivation toward more similar science experiences within the student (3).

An additional characteristic of mastery learning is that student failure on a given objective is accompanied by 1) immediate and specific feedback regarding the reason for the failure and 2) at least one alternative route leading to remedial instruction.

Patterns of Student Activities

Describing a typical student's weekly schedule is quite difficult since so many combinations of the required and optional activities are possible. However, in general terms, and realizing that a student may select several options, here is one possible schedule for a six period week:

Period 1	observe demonstrations, participate in discussions, attend lecture
Period 2	attend background lecture
Period 3	select one or more optional activities based on developing interest
Period 4	perform the assigned laboratory experiment
Period 5	participate in discussion and inquiry session
Period 6	optional activities, mastery performance, behavioral objectives content quiz

A deliberate and recurring pattern has been built into this schedule. Initially, an attempt is made to arouse the student's interest and immediately direct it toward a new topic. Next, the student is provided with more basic information through lecture. Then once again the student is directed to an assigned activity designed to increase the level of the student's conceptual view of the subject. At this point the teacher is able to expand and add to existing ideas through genuine inquiry and discussion. The typical student may now prepare to "inquire" into the higher level intriguing aspects of the course.

Once this is achieved, the evaluation may be completed, mastery preparation for the succeeding topic may be performed and the cycle is ready to begin anew.

Figure 1 depicts a flowchart which lists numerous optional paths available to the student in the Boyertown Physics Project.

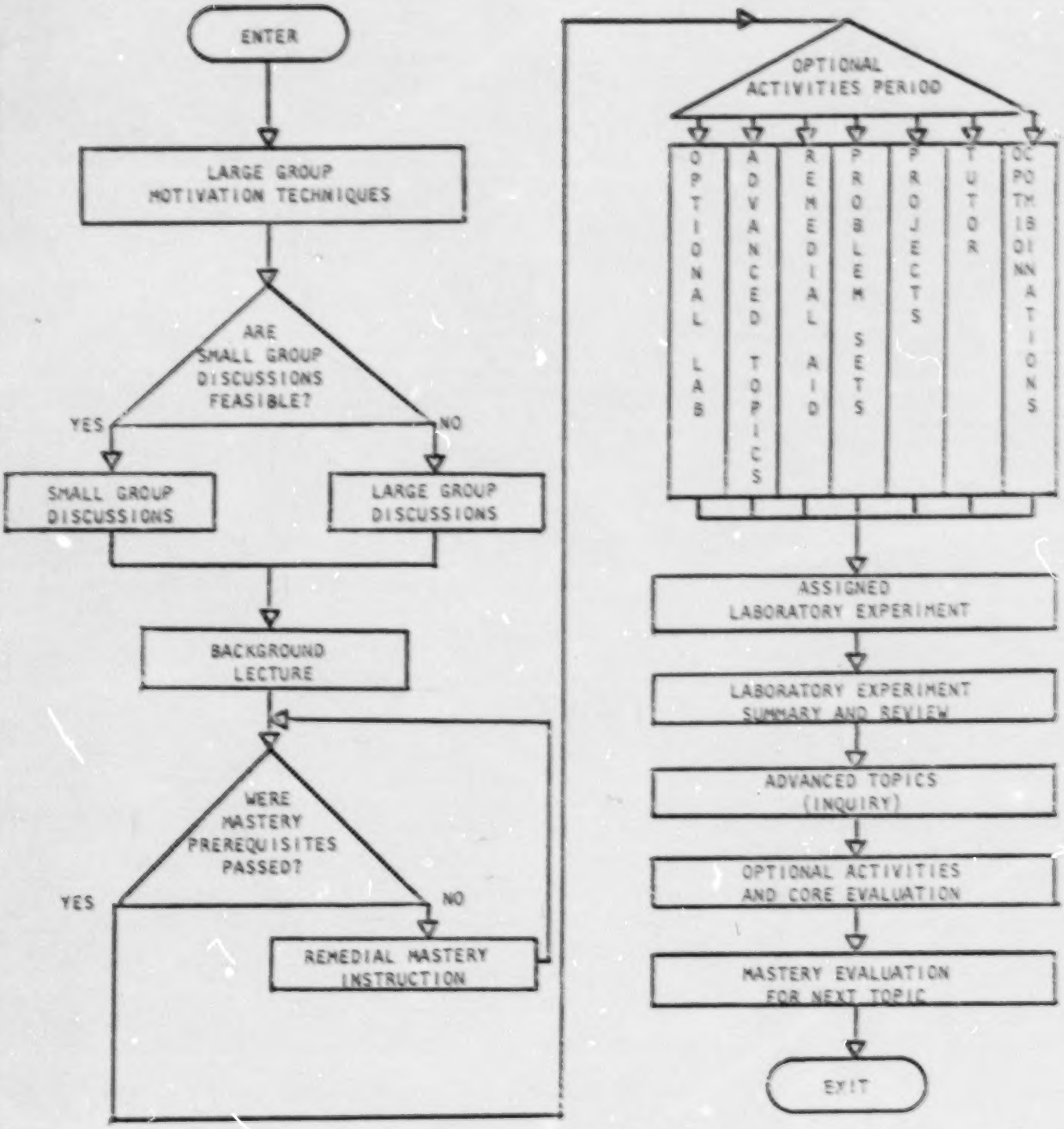

FIGURE 1

Flowchart Representation of Study Sequence for a Typical Student

RESULTS

Grading remains an important part of the program. Within the Boyertown Project, grade averages are the result of the following four major contributing factors: individualized laboratory experiences, mastery achievement, core quizzes, and core unit tests. Each factor is equally weighed. In addition to the above an anecdotal record is maintained for each student. Such a record frequently may yield justification for the alteration of the final grade when unusual circumstances prevail. Typical record entries note special interests, class contributions, ideas given, behavioral analysis, and projects completed.

Student Reaction

Student response toward the program has been most interesting. Approximately fifteen percent of the students enrolled in physics classes are participating in teacher supervised research projects. An examination of the students' responses to a project questionnaire (administered at the end of the 1972-73 school year) shown in Figure 2 illustrates clearly and concretely a high level of confidence within the students.

The implication that physics is not as difficult as students thought it would be has tremendous advertising potential. Hopefully it will offset the tendency for certain high ability students to 'protect' grades by opting for less difficult courses (7).

Another significant observation may be made concerning enrollment. After the first year of the project, physics enrollment increased 20% (86 to 103 students). Enrollment for the 1973-1974 physics program shows a 22% increase over this year (103 to 126). Furthermore, interest among currently participating eleventh grade students was great enough to warrant the addition of a second year physics course to the curriculum.

Students were asked to circle their opinion. If they felt strongly about any question, they were permitted to indicate their feeling by writing a (+) over the yes or a (-) over the no on the answer sheet. A table showing the results is below.

CIRCLE YOUR OPINION (94 students survey)*			%Yes	%No
1.	yes no	Do you favor the idea of having several labs from which to choose on lab day?	95	5
2.	yes no	Have the student assistants been of help to you during lab periods or optional activity periods?	58	42
3.	yes no	Do you like the idea of having optional activity periods?	93	7
4.	yes no	Have the mastery exercises within our course helped you insofar as preparing you to solve problems, use your slide rule, etc.?	60	40
5.	yes no	Does knowing my objectives help you while preparing for quizzes and tests? (i.e. when I tell you what you should be able to do for the tests, etc.)	88	12
6.	difficult easy	When you began this course, did you expect physics to be easy?	14	86
7.	yes no	Do you sincerely feel you have been learning much physics from this course?	81	19
8.	more difficult easier	Is physics easier than you had expected?	72	28

*nine students did not write this survey

FIGURE 2

Summary of Responses of 94 Students to Selected Questions Regarding the Boyertown Project

Any change in a curriculum raises questions relative to academic quality. The area of academic achievement was studied after the administration of the Dunning-Abeles Final Physics Examination (9). Prior to the exam, students were informed that the test results would be used to measure course effectiveness and would not affect individual term or final grade in any way. The results of this final examination are shown in Figure 3.

The scores were converted into percentile ranks using national norm tables provided by the publisher (9). Three separate groups (based upon vocational interests expressed at the beginning of the course) were formed; their separate and combined ranks are tabulated. As anticipated, those in Group 1, which included college-bound science majors as well as two-year technical school hopefuls, scored highest and earned an elevated range of scores.

The non-science, college-bound persons (Group 2) scored somewhat below the national norm. Interestingly, there were students in Group 2 who scored higher than some in Group1. There were nine students who classified themselves into Group 3. Although their group mean was quite depressed, at least one person in the group learned more than some students in Groups 1 and 2. The fact that nine non-college bound students elected to take physics presents some valuable data about the project.

The group mean for all students was two percentile points below the national norm data provided. It is quite likely that had the test been given under different circumstances (i.e., had the students been told their score would affect their grade), the mean would have been predictably higher.

It appears that the project is increasing enrollment, stimulating interest, teaching physics, and providing a new degree of individualization for the students of physics at Boyertown.

Group	Number	%ile range	%ile mean
1. Students who responded at the start of the school year that they were considering a technical career.	31	58 - 25	65
2. Students who responded at the start of the school year that they were considering college attendance but not a technical career.	56	93 - 1	40
3. Students who responded at the start of the school year that they were neither college bound nor considering a technical career.	9	69 - 6	28
Summary of all students	96*	98 - 1	48

*Seven students did not write this exam

FIGURE 3

Summary of Group Means on the Dunning-Abeles Physics Test (Administered June, 1973)

The Boyertown project, as described, is simply a carefully balanced integration of several of the best known teaching strategies now available to us. Our experiences with this program of major commitment have been extremely satisfying. Genuine interest and response from a vast majority of participating students has been witnessed. The program is not earth-shattering in scope and will not be a "panacea" for all that "ails" physics programs today. It is, however, an example of how-to-do-it as far as developing an improved physics program using the recent findings of current educational research and exemplar educational programs. It represents a realistic step that may be taken toward providing a more effective physics program in your school.

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